EFFECT OF BOXING MATCH ON METABOLIC HORMONAL AND INFLLAMATORY PARAMETERS IN MALE BOXERS

By

SAPNA GOSWAMI

Reg. No.: PH2014-11

Supervisor

Dr. DEEPAK SHARMA

A Synopsis Submitted to

DEPARTMENT OF EXERCISE PHYSIOLOGY

LAKSHMIBAI NATIONAL INSTITUTE OF PHYSICAL EDUCATION, GWALIOR

For the award of the degree of

Doctor of Philosophy in Physical Education

July 2021

CHAPTER I

INTRODUCTION

In the modern landscape, the way individuals participate in and achieve success in professional sports is shaped by interdisciplinary insights. Elite athletic performance is influenced by an interplay of physical, physiological, psychological, and biochemical components. While a robust physique is fundamental, contemporary training programs also emphasize the development of technical skills and tactical awareness. Such training prioritizes the improvement of various physical fitness domains, which subsequently contributes to physiological enhancements and biochemical adaptations. Professional coaches acknowledge that athletic potential arises from a combination of diverse factors. They argue that cultivating the athlete's overall character is just as important as optimizing their performance, making the pursuit of sporting excellence an increasingly specialized and multifaceted endeavor.

Scientific research continues to support various dimensions of athletic performance, leading sports organizations to endorse evidence-based training practices. As a result, athletes, alongside their coaches and trainers, actively seek innovative methods and techniques to elevate performance levels. Physical fitness remains a cornerstone of athletic competence, as success in sports demands superior endurance, strength, flexibility, and agility. To maintain these capabilities, medical professionals have become integral members of most sports teams, contributing both physical and psychological support during training. These specialists—proficient in physiology, nutrition, mental health, and neurology—collaborate with coaches to formulate optimized training regimes for athletes(Martín-Rodríguez et al., 2024).

It is widely accepted that achieving optimal performance requires adherence to core principles of athletic training and structured periodization. To boost athletic outcomes in competitive environments, sports scientists continually evaluate diverse performance-enhancing approaches, including the integration of practices such as yoga. Sports physiology, as a scientific discipline, spans an extensive array of research themes. This review seeks to synthesize these diverse interests into a unified direction for future investigations in the field. A key objective is to explore how sports physiology can further the development of high-performance athletes. The review provides a critical examination of existing knowledge and highlights areas where further inquiry could substantially advance both theoretical understanding and practical implementation of sports physiology. It focuses on the physiological thresholds of elite athletes and how training stimuli can induce overload, emphasizing the need for strategic adaptation and recovery in the face of rigorous training demands.

Moreover, the increasing dependence of sports physiology on sophisticated analytical tools and data-driven approaches is acknowledged. A major ambition within sports science research is the application of efficient, flexible equipment and protocols that can be adapted

across various training environments—especially crucial in high-intensity competitive contexts. Much of the existing research has centered on biomechanical and physiological assessments, which are considered essential indicators of performance and are highly valued for training optimization.

In recent years, the physiology of sports and human movement has emerged as one of the most discussed and evolving research fields. This area integrates biochemistry and biological sciences and is now significantly shaped by advancements in big data analytics, computational modeling, and artificial intelligence. The field of Sports and Exercise Medicine aims to bridge the gap between sports science and health science, encompassing domains such as wellness, rehabilitation, exercise load management, performance diagnostics, and strength and conditioning (Joyner & Coyle, 2008). The integration of research findings into practical applications assists coaching staff in designing training loads that minimize the risks of injuries and illnesses while accelerating the recovery process (Jakeman et al., 1994)

Boxing is a regulated combat sport where two individuals, equipped with protective gloves, engage in striking each other with their fists for a predetermined duration. Like other martial arts, boxing carries inherent health risks, and in some cases, injuries sustained in the ring have historically resulted in fatalities. A core component of training in professional boxing is sparring—controlled practice bouts that prioritize tactical and technical skill development over brute strength. Scientific evidence indicates that physical exercise, particularly at competitive levels, induces notable shifts in various biochemical blood parameters.

Boxing is contested at both amateur and professional levels, where athletes follow the Queensberry rules. These regulations govern the conduct of matches, ensuring fighters compete within designated weight categories while aiming to land effective punches and evade their opponents' strikes. Success in matches is typically determined by points accrued through clean hits or by rendering the opponent unable to continue. Standard boxing matches are composed of 3 to 12 rounds, each lasting approximately three minutes. The sport is known for its intensity and the high level of physical coordination it demands. Despite its popularity, research on how boxing influences hematological and biochemical parameters remains scarce. Moreover, the effects of different exercise regimens on hormonal responses, metabolic markers, and energy consumption have not been thoroughly explored. Sports scientists specializing in combat sports emphasize the importance of understanding the physiological adaptations triggered during bouts, as these insights are crucial for enhancing athlete performance (Lee et al., 2017).

Athletic improvements are closely tied to physiological adaptations that promote efficient energy utilization during matches without impairing energy output. The energy demands of boxing are met through both aerobic and anaerobic metabolic systems, with the dominant pathway depending on the duration and intensity of activity. The sport involves rapid, high-intensity actions interspersed with short rest periods, often insufficient for complete recovery. This pattern leads to lactate build-up and a rise in blood lactate concentration (de Lira et al., 2013).

The extreme exertion required in boxing causes a continuous elevation in heart rate and lactate levels throughout the bout. For this reason, it is critical for both athletes and coaches to be aware of the underlying biochemical shifts that occur with sustained physical activity. Monitoring such markers provides valuable information on how the body adapts to training and can help prevent overtraining. Therefore, coaches must understand exercise physiology to create training programs that boost performance while minimizing fatigue and injury risks (Karadağ et al., 2021).

Biochemical assessments are essential tools for evaluating an athlete's physical condition, training load, and overall well-being. As a field of biological science, biochemistry investigates the molecular processes that support life, including molecule synthesis, transformation, and degradation. Routine biochemical evaluations help athletes track their health and optimize performance. Key indicators such as glucose, hemoglobin, uric acid, urea, creatinine, and cholesterol levels have strong associations with athletic output, particularly in physically demanding sports like boxing (Manna et al., 2010)

Regular physical activity improves fitness and offers long-term health protection, though participation in extreme sports may carry substantial physical risks, including life-threatening conditions. While some disciplines promote both mental and physical health, they may also pose health challenges. Evaluating biochemical and hematological markers is common in disease diagnosis and monitoring, influencing a significant portion of clinical decisions. However, such tests are subject to biological variability, which can affect interpretation (Malm et al., 2019). This variability includes individual factors such as exercise habits, diet, stress, body posture, circadian rhythms, menstrual cycle, pregnancy, age, sex, and environmental influences like climate and altitude. Hence, when interpreting laboratory results from physically active individuals, it is essential to recognize that training-induced physiological adaptations can result in deviations from standard reference values. Exercise impacts lab parameters across short, medium, and long durations, depending on the type, intensity, and length of activity as well as the recovery process that follows. The biological characteristics of molecules, exercise frequency, and the nature of recovery all influence the rate at which biomarkers appear and clear from circulation (Chaabène et al., 2015).

Numerous studies have examined how physical activity influences clinical chemistry, hematology, and coagulation tests, emphasizing the importance of considering exercise as a pre-analytical variable. These reviews highlight how regular and intense physical activity can lead to marked changes in biomarker levels. They also explore the effects of various exercise modalities on laboratory readings. Crucially, deviations from reference ranges in athletes may signify injury, disease, or normal physiological adaptation. Differentiating between these outcomes is essential for accurate interpretation and for making informed decisions about medical interventions or training adjustments (Sanchis-Gomar & Lippi, 2014).

Biological variability encompasses a broad range of intrinsic and extrinsic factors that influence biomarker levels. These include individual characteristics such as physical activity, diet, emotional stress, posture, menstrual cycle, circadian rhythm, pregnancy status, lifestyle

habits, age, and sex, as well as environmental elements like altitude and climate. For this reason, interpreting biomarker values in athletes requires caution, as the physiological adaptations resulting from consistent training or acute physical exertion may cause results to fall outside standard clinical reference ranges. Exercise, depending on its intensity and duration, can significantly influence various laboratory parameters across short-term, medium-term, and long-term timeframes. Several critical factors determine how exercise affects biomarker dynamics, including the biochemical nature of the molecules involved, exercise intensity, frequency, type, and recovery time. The body's ability to synthesize, release, and clear these substances during and after physical exertion is tightly regulated by these variables (Chaabène et al., 2015)

Multiple research studies have investigated the impact of physical activity on laboratory-based assessments related to clinical chemistry, hematology, and coagulation. These studies consistently highlight that exercise acts as a critical pre-analytical variable, altering biomarker levels in both acute and chronic contexts. Narrative reviews in this area aim to clarify how exercise-induced changes manifest across different populations, particularly athletes who routinely engage in high-volume or high-intensity training. The effects of various exercise types—such as resistance training, endurance events, and mixed-modality routines—on laboratory measures are also well-documented. Importantly, when interpreting laboratory findings in trained individuals, deviations from normative biomarker values do not always indicate pathology. Instead, they may represent beneficial physiological adaptations or responses to exercise-induced stress. For instance, fluctuations in inflammatory markers or enzyme levels might reflect enhanced muscle activity or repair mechanisms rather than injury. Understanding these nuances is critical for medical professionals and coaches, enabling them to differentiate between normal exercise responses and early signs of overtraining or injury (Sanchis-Gomar & Lippi, 2014)

Voluntary physical activities can be categorized based on their nature and intensity. These include endurance-based continuous activities like long-distance cycling or running, dynamic efforts involving repetitive movement, or static (isometric) exercises that involve muscle contractions without significant motion. Additionally, exercises can be either exhaustive or non-exhaustive and performed under aerobic or anaerobic conditions (Finsterer, 2012). For example, sprinting is considered a high-intensity, short-duration anaerobic exercise, while isometric holds demand sustained muscular effort without movement. The physiological responses elicited by these activities vary significantly depending on the individual's level of conditioning. A moderately paced cycling session may be manageable for an elite endurance athlete but extremely taxing for a sedentary individual. As a result, the same exercise can provoke distinct biochemical and hematological responses across individuals with different fitness levels.

In less-trained individuals, even mild-to-moderate physical activity can lead to noticeable biomarker shifts. In contrast, well-trained athletes often exhibit biochemical changes only after extended or intense activities, such as marathon running or ultra-endurance events. Hence, fitness level plays a crucial role in determining the magnitude and

nature of the body's response to physical exertion. Accurate interpretation of biomarker data thus necessitates a contextual understanding of both the exercise characteristics and the athlete's baseline physiological profile .(Herbert et al., 2020) (Sanchis-Gomar & Lippi, 2014). Metabolic indicators have a substantial impact on athletic performance, making biochemical testing an essential tool for evaluating and comparing the effectiveness of different training protocols. Functional testing allows coaches and sports scientists to identify how distinct training strategies influence physiological systems. Changes in biochemical markers offer direct insight into the body's adaptation to physical stress and help determine whether a training program is yielding beneficial effects. In sports like kickboxing, where athletes rely heavily on anaerobic energy systems, studies have revealed strong associations between these metabolic demands and the physical attributes of the athletes, particularly their endurance capacity. Assessing biochemical profiles in such disciplines can help gauge the efficacy of specific training regimens. Furthermore, the balance between oxidative stress and the body's antioxidant defense systems plays a crucial role in understanding an athlete's physiological readiness. An imbalance between these systems can negatively influence performance and limit physical potential.

Recent research suggests that the strategic use of natural antioxidants may enhance recovery and reduce oxidative stress levels in athletes (Karadağ et al., 2021). To assess athletes' preparedness and physiological responses, it is vital to monitor enzymes associated with antioxidant activity, as well as biomarkers linked to lipid peroxidation. The interplay between the lipid peroxidation system (LPS) and the antioxidant system (AOS) is particularly relevant in predicting the risk of muscle damage and stress-related conditions. An athlete's antioxidant capacity serves as a reliable indicator of their physiological resilience, helping predict their potential to reach peak performance while minimizing injury risk. Despite its significance, there remains a lack of comprehensive studies examining the roles of lipid peroxidation and antioxidant defense mechanisms in kickboxing or similar high-intensity combat sports. The relationship between training intensity and the functioning of these systems continues to be poorly understood (Muñoz Marín et al., 2018)

Insulin, a central anabolic hormone, is produced by the beta cells of the pancreas and regulates the metabolism of carbohydrates, fats, and proteins. It facilitates glucose uptake in the liver, adipose tissue, and skeletal muscles. When insulin levels are low, the body shifts toward a catabolic state, breaking down stored fat for energy. Conversely, high insulin levels suppress hepatic glucose production, promoting energy storage. The secretion of insulin is directly influenced by fluctuations in blood glucose, increasing in response to hyperglycemia and decreasing during hypoglycemia.

In contrast, glucagon—a hormone secreted by pancreatic alpha cells—elevates blood glucose levels through processes like gluconeogenesis and glycogenolysis. The complementary actions of insulin and glucagon help maintain glucose homeostasis. Dysfunction in insulin activity, as seen in diabetes mellitus, results in hyperglycemia. Type 2 diabetes involves insulin resistance and reduced insulin secretion, while type 1 diabetes stems from autoimmune destruction of beta cells (Wilcox, 2005)

Structurally, human insulin consists of 51 amino acids forming a heterodimer linked by disulfide bonds between its A and B chains. Before the development of recombinant insulin, porcine insulin—closely resembling human insulin—was widely used in diabetes management. Insulin secretion by pancreatic beta cells occurs in two distinct phases. The first is a rapid release that happens shortly after blood glucose levels rise, followed by a second, more prolonged release phase that involves newly synthesized insulin granules and is less directly dependent on glucose levels. During periods of physiological stress, the hormone norepinephrine (noradrenaline) inhibits insulin secretion, allowing blood glucose levels to rise. Once homeostasis is restored, insulin release ceases. If blood glucose falls below the normal threshold, insulin secretion is suppressed, and hyperglycemic hormones like glucagon are activated to restore balance (Cerf, 2013)

Persistent hyperglycemia or hypoglycemia, if left untreated, can result in serious health complications. Notably, insulin has also been misused in strength and endurance sports, often in conjunction with anabolic steroids and growth hormones. While anabolic agents and GH promote muscle hypertrophy, insulin contributes by preventing muscle catabolism. Furthermore, somatotropin (growth hormone) can impair glucose uptake in muscle cells—a side effect that insulin helps counterbalance. Among endurance athletes, synthetic insulin is sometimes used to enhance glycogen storage in muscles, thereby improving stamina and aerobic performance (Vargas et al., 2024)

A well-publicized incident occurred during the 2001 Giro d'Italia when a syringe containing insulin was found in cyclist Marco Pantani's hotel room, resulting in his suspension. The misuse of insulin among athletes and bodybuilders continues to raise concerns, not only due to the performance advantage it offers but also because of the severe health risks it poses to non-diabetics. According to Dr. Peter Sonksen, a professor of endocrinology at St. Thomas' Hospital in London, insulin use presents a serious threat to fair play in sports. In healthy individuals, improper insulin use can cause life-threatening glucose imbalances and even death. Dr. Sonksen's research, published in the *Journal of Endocrinology*, underlines the gravity of this issue. Dr. Doug McKeag from the Indiana University Center for Sports Medicine notes that insulin's performance-enhancing effects in athletes may mirror its therapeutic benefits for diabetic patients. Insulin enhances the efficiency of glucose uptake by enabling its transport into cells, which in turn fuels energy production. Dr. Sonksen also points out that insulin delivery systems could, in theory, improve endurance and recovery following intense exercise. Some bodybuilders believe insulin contributes to muscle development, although the extent of its use among athletes remains uncertain due to its limited accessibility and short half-life—approximately four minutes once it enters the bloodstream.

Several hormones regulate how the body utilizes its energy resources. Insulin and insulin-like growth factor 1 (IGF-1) assist in transporting glucose, amino acids, and fatty acids into muscle tissue, promoting anabolic processes. On the other hand, growth hormone (GH) and cortisol are primarily associated with catabolic functions, initiating the breakdown of stored energy to meet physiological demands (Röder et al., 2016).

Blood glucose, or blood sugar, refers to the concentration of glucose circulating within the bloodstream. This level is influenced by various hormones, particularly stress-related ones like adrenaline and cortisol, which can elevate glucose levels in response to physical or psychological strain. Chronic elevation of cortisol has been associated with increased appetite, abdominal fat accumulation, insulin resistance, and a heightened risk of cardiovascular disease (Wilcox, 2005)

Hemoglobin, the iron-containing protein found in red blood cells, plays a vital role in oxygen transport. It binds to oxygen in the lungs and releases it into tissues throughout the body. Glycogen, the stored form of glucose, serves as a key energy source for both anaerobic and aerobic metabolism. It is synthesized from dietary carbohydrates such as starches, sucrose, lactose, galactose, and fructose, and is stored primarily in the liver and muscle tissues. During periods of fasting or high energy demand, glycogen reserves are broken down to maintain blood glucose levels. In eukaryotic organisms, including humans, aerobic metabolism of glucose provides the bulk of cellular energy (Marengo-Rowe, 2006)The regulation of glucose and glycogen metabolism is orchestrated by the interplay of insulin and glucagon, both secreted by the pancreas. Glucagon is dominant during fasting states, promoting glycogen breakdown, while insulin is released postprandially to facilitate glycogen synthesis and glucose storage.

The body uses different glucose transporters depending on the tissue type. These include sodium-dependent transporters (SGLTs) and sodium-independent ones (GLUTs). SGLTs are key for intestinal glucose absorption and renal reabsorption, whereas GLUT1 and GLUT2 regulate glucose handling in the liver. GLUT4, an insulin-sensitive transporter, is primarily responsible for glucose uptake in muscle and adipose tissue. During digestion, carbohydrates are broken down into glucose, which constitutes about 80% of the absorbable monosaccharides. Fructose and galactose are also converted to glucose in the liver. Liver enzymes facilitate the interconversion of these sugars and help maintain glucose equilibrium by regulating its entry and exit across the liver cell membrane (Physiology, Glucose - StatPearls, n.d.).

The metabolism of glucose is under hormonal control. Insulin and IGF-1 enhance the cellular uptake of glucose, amino acids, and fatty acids, supporting anabolic processes such as tissue growth and repair. In contrast, growth hormone exerts both anabolic and catabolic effects, while cortisol primarily acts as a catabolic hormone, mobilizing energy stores through gluconeogenesis and lipolysis. Because glucose is a principal fuel source during physical activity, especially at higher intensities, exercise stimulates an increase in blood glucose levels. This response is due to the mobilization of glucose from muscle and liver glycogen stores to meet energy demands. Studies in both human and animal models have shown that acute exercise enhances insulin sensitivity, thereby improving glucose transport into muscle cells. This ensures an adequate energy supply to support sustained muscular contractions.

Sufficient insulin levels facilitate the entry of glucose and amino acids into cells, fueling energy production and muscle repair. Research further indicates that insulin and

glucose levels rise following intense physical exertion, helping to replenish glycogen stores and restore metabolic balance (Anderson et al., 2018)

Lactate, the ionized form of lactic acid, is produced during anaerobic metabolism when energy is generated from glucose in the absence of sufficient oxygen. While small quantities of lactate are present in the bloodstream under resting conditions, its levels rise significantly when the body's ability to clear it is surpassed by the rate of production. This elevation can result from tissue hypoxia, impaired lactate clearance, or increased metabolic demand. Situations range from systemic medical emergencies, such as septic shock, to localized increases in muscle activity during strenuous exercise. The "lactate shuttle" theory, originally proposed by George Brooks in 1984, has since become foundational in our understanding of lactate's role in metabolism. This concept suggests that lactate is not merely a waste product but functions as a crucial intermediary, facilitating energy exchange between tissues. Numerous experimental studies have supported this model, demonstrating that lactate serves as a carbohydrate-derived energy source—sometimes surpassing glucose flux during moderate exercise.

Importantly, elevated lactate concentrations are not necessarily indicative of oxygen deficiency or pathological conditions. The body can eliminate lactate from the bloodstream as quickly as it is produced, particularly when trained for such efficiency. Therefore, for clinicians and sports professionals, understanding the normal and exercise-induced variations in lactate levels is essential. Such measurements are frequently employed to evaluate energy system efficiency in athletes and to detect underlying metabolic disturbances in chronically fatigued or ill individuals. Accurate lactate measurement is vital for correct interpretation, often requiring validation using enzymatic assay techniques to ensure reliability (Goodwin et al., 2007).

While not always integrated into daily training routines, lactate testing is highly effective for tracking an athlete's progression across training cycles. By measuring lactate in conjunction with heart rate, running pace, or power output, coaches and athletes can gather meaningful performance insights. Comparing lactate data across time points helps identify improvements in aerobic and anaerobic thresholds. A notable application of lactate data is the identification of the OBLA (Onset of Blood Lactate Accumulation) point. This threshold helps determine optimal performance pacing and serves as a reference in both lab-based and field training. As training advances, athletes typically show reduced blood lactate concentrations at equivalent intensities, indicating improved lactate clearance and tolerance. This is partly due to physiological adaptations that enhance the body's ability to reabsorb and utilize lactate efficiently.

Although limited, clinical research underscores lactate's importance. For instance, individuals with McArdle's disease, a rare metabolic disorder, are unable to produce lactate during exercise. This deficiency illustrates lactate's critical role in energy metabolism. Elevated lactate levels are also associated with an increase in hydrogen ion concentration (H^+), contributing to metabolic acidosis—a serious condition often linked to renal dysfunction and other systemic diseases (Rabinowitz & Enerbäck, 2020).

Triglycerides are the most abundant form of fat in the human body, accounting for approximately 95% of dietary fats. They are primarily found in food sources such as oils, butter, and animal fats. When caloric intake exceeds energy expenditure, the surplus calories are converted into triglycerides and stored in adipose tissue. These stored fats are later mobilized to supply energy during periods of physical exertion or caloric deficit. Circulating triglycerides are transported by very low-density lipoproteins (VLDL) to various tissues throughout the body.

Elevated triglyceride levels are commonly observed in individuals who are overweight or obese and are associated with an increased risk of developing cardiovascular diseases, atherosclerosis, pancreatitis, and metabolic syndrome. High triglycerides can also indicate other underlying conditions that contribute to heart disease and stroke. While triglycerides function primarily as an energy reserve, cholesterol plays essential roles in cell membrane structure and the synthesis of specific hormones.

Research by Chatterjee et al. (2007) demonstrated that female boxers engaging in regular training exhibited favorable changes in lipid profiles. After six weeks of structured training, notable improvements were observed in their blood lipid parameters, indicating enhanced cardiovascular health and metabolic efficiency. .(Chatterjee et al., 2007)

Consistent physical activity has been shown to elevate high-density lipoprotein (HDL) levels, which can help lower the risk of arterial plaque formation. However, the effects of a single bout of high-intensity exercise on lipid profiles remain inconsistent across studies. For instance, a 2023 study by Swati Trimbak investigated how a one-hour session of intense exercise influenced lipid levels in women who had been training regularly for over a year. The study assessed key markers, including total cholesterol (TC), triglycerides (TG), low-density lipoprotein (LDL), very-low-density lipoprotein (VLDL), and HDL. HDL and LDL are the two main cholesterol-carrying lipoproteins in the bloodstream. HDL, often termed "good cholesterol," facilitates the removal of excess cholesterol by transporting it to the liver for excretion. In contrast, LDL or "bad cholesterol" delivers cholesterol to peripheral tissues, where it can accumulate in arterial walls. This buildup contributes to the formation of atherosclerotic plaques, increasing the risk of coronary artery disease, heart attack, and stroke. Excess LDL interacts with other substances in the blood, forming deposits that can obstruct blood flow and lead to serious cardiovascular events.

The clinical evaluation of LDL levels depends on factors such as age, family history, and personal risk profile. Emerging research also emphasizes that the structure and functionality of HDL particles—including their size, lipid and protein composition, and antioxidant capacity—may be more critical than mere concentration. Key functions of HDL include facilitating cholesterol efflux, reducing oxidative stress, and exerting anti-inflammatory and anti-thrombotic effects. Aerobic exercise has consistently been shown to improve HDL-C concentrations while lowering levels of LDL-C and triglycerides. Regular training also contributes to the maturation and improved functionality of HDL particles. These changes support better cardiovascular health by optimizing the blood lipid profile.

While acute bouts of exercise may cause only minimal shifts in lipid levels, long-term physical activity has been found to yield more profound and sustained improvements. Previous research by Cullinane et al. (1981) highlighted that the magnitude of change in plasma lipid profiles depends on the type, duration, and intensity of the exercise performed. (Cullinane et al., 1981)

Studies show that athletes and physically active individuals typically display healthier lipid profiles compared to sedentary counterparts. For example, bouts of high-intensity effort in female boxers have been associated with reductions in body fat, increases in hemoglobin, and beneficial changes in total cholesterol, triglycerides, and HDL-C. Maintaining a balanced HDL-to-LDL ratio is critical to cardiovascular function and overall metabolic health.

Cardoso Saldaña's findings indicated that regular exercise positively affects lipid profiles, although the outcomes vary based on training specifics (Cardoso Saldaña et al., 1995). Additional research by Enger et al. (1977) confirmed that aerobic exercise boosts HDL-C levels and improves the ratio of HDL to total cholesterol. However, a contrasting study by Khanna and Manna (2006) found increased levels of total cholesterol, triglycerides, and LDL-C in individuals undertaking extensive aerobic training, suggesting that other variables such as diet and recovery may also influence lipid metabolism. (Enger et al., 1977)

In another study conducted by Chatterjee et al., lipid profiles of 45 female boxers were analyzed before and after a six-week training intervention. The post-training results revealed statistically significant improvements in lipid levels, further confirming the role of regular, structured physical activity in enhancing cardiovascular markers. Creatinine is a waste product generated from the normal metabolism of creatine, a compound that plays a key role in supplying energy to muscles. Roughly 2% of the body’s creatine is converted into creatinine daily and subsequently filtered out by the kidneys through urine. Since muscle mass remains relatively constant in most individuals, creatinine production tends to be stable. As a result, serum creatinine levels are commonly used to evaluate renal (kidney) function.

Elevated serum creatinine levels may indicate impaired kidney function or renal disease, though high levels can also result from increased muscle mass, dehydration, or intense physical activity. This makes it essential to interpret creatinine values within the appropriate physiological and training context—especially in athletes.

Athletes, particularly those engaged in resistance training or high-intensity sports like boxing, often exhibit temporarily elevated creatinine levels following intense exercise. This occurs due to increased muscle turnover and higher creatine phosphate usage during physical exertion. While this elevation is typically transient and not pathological, it highlights the need for caution when using creatinine as a sole diagnostic indicator in athletic populations. Creatinine levels are influenced by a variety of factors including age, sex, muscle mass, hydration status, and physical activity. Normal serum creatinine concentrations are generally higher in males than females due to greater average muscle mass. In highly trained individuals, particularly strength or power athletes, creatinine values may be at the upper end of—or even slightly above—the normal clinical range without indicating renal dysfunction.

Creatinine clearance, a metric that estimates the glomerular filtration rate (GFR), is often used alongside serum creatinine to provide a more comprehensive assessment of kidney health. However, intense physical training may transiently reduce GFR due to increased blood flow to working muscles and alterations in renal hemodynamics.

Another consideration is the use of creatine supplements by athletes, which can affect both creatine and creatinine concentrations. Creatine supplementation enhances intramuscular energy reserves, promoting improved performance in short-duration, high-intensity efforts. Nonetheless, its use may lead to mild increases in serum creatinine, which, if not interpreted appropriately, could be mistaken for renal impairment. Understanding the role of creatinine in exercise physiology allows coaches, trainers, and sports physicians to distinguish between exercise-induced changes and clinically relevant findings. Accurate assessment requires awareness of training load, recovery status, dietary practices, and hydration—each of which can influence biochemical markers in active individuals.

Alanine aminotransferase (ALT), also known as serum glutamate-pyruvate transaminase (SGPT), is an enzyme primarily found in liver cells, though smaller amounts exist in skeletal muscles and other tissues. It plays a key role in amino acid metabolism by facilitating the conversion of alanine and α-ketoglutarate into pyruvate and glutamate. ALT is released into the bloodstream when liver cells are damaged, making it a sensitive marker of hepatic injury. However, elevated ALT levels can also result from intense physical exertion, particularly when muscle breakdown occurs. Aspartate aminotransferase (AST), or serum glutamic-oxaloacetic transaminase (SGOT), is another enzyme involved in amino acid metabolism. Unlike ALT, AST is distributed across several tissues, including the liver, heart, skeletal muscles, kidneys, and brain. While elevated AST levels may signal liver dysfunction, they are also strongly associated with muscle damage—particularly in athletes engaged in high-intensity or prolonged exercise.

ALT and AST are often assessed together to differentiate between liver and muscle sources of enzyme elevation. In sports and exercise settings, temporary increases in these enzymes can occur after strenuous activity due to muscle stress rather than liver pathology. Therefore, interpreting enzyme levels in athletes requires an understanding of training intensity, recovery periods, and other contributing factors. Lactate dehydrogenase (LDH) is a third enzyme commonly used as a biomarker of cellular damage and inflammation. It catalyzes the interconversion of lactate and pyruvate, playing a crucial role in anaerobic energy metabolism. LDH is widely present in the body, including the liver, muscles, heart, lungs, and blood cells. When tissue damage occurs—whether due to injury, inflammation, or intensive exercise—LDH is released into the bloodstream.

Elevated LDH levels are frequently observed after vigorous physical activity and may reflect muscle cell membrane disruption, particularly following eccentric or impact-heavy movements like those involved in boxing. These increases are typically transient and resolve with adequate rest and recovery. However, consistently high LDH values may suggest ongoing inflammation, insufficient recovery, or underlying tissue damage.

Monitoring ALT, AST, and LDH levels can offer valuable insight into how an athlete's body is responding to training loads. This information is useful for optimizing training regimens, identifying early signs of overtraining or muscle strain, and preventing more severe injuries. Coaches and sports medical personnel often use enzyme profiling in combination with other physiological markers to make informed decisions about recovery strategies and workload adjustments.While temporary fluctuations in these enzymes are considered a normal part of training adaptation, persistently elevated levels should be evaluated carefully to rule out pathological causes. Nutritional deficiencies, dehydration, overreaching, and undiagnosed medical conditions may also influence enzyme activity and must be considered in the interpretation of results.

In summary, ALT, AST, and LDH are critical biochemical markers for assessing the physiological impact of exercise, particularly in high-intensity, contact sports like boxing. When measured and interpreted appropriately, they contribute significantly to understanding muscle stress, systemic inflammation, and the body's recovery status during rigorous training and competition phases.

STATEMENT OF THE PROBLEM

The Problem is entitled as 'effect of boxing matches on some selected metabolic, hormonal and inflammatory parameters in boxers'.

OBJECTIVE OF THE STUDY

There are following objectives of the study.

- To ascertain the effect of boxing sparring on selected metabolic parameters of boxers.
- To find out the effect of boxing sparring on selected hormonal parameters of boxers.
- To find out the effect of boxing sparing on selected inflammatory parameters of boxers.

DELIMITATIONS

1. The study will be confined to National level male boxers of Madhya Pradesh and Uttarakhand.

2. The study will be delimited to boxer's age ranging between 17-25 years.

3. The study will be further delimited to 20 to 30 boxers.

4. The study will be further delimited to the following metabolic parameters.

- Insulin
- Glucose
- Lactate level
- Triglycerides
- Total cholesterol
- HDL
- LDL
- Creatine

5. The study further delimited to following hormonal parameters.

- ACTH
- GH
- Cortisole

6. The study further delimited to following inflammatory markers.

- ALT
- AST
- Lactate dehydrogenase

HYPOTHESIS

On the basis of knowledge gained from available literature, research findings and the scholar's own understanding of the subject area, the following hypothesis is formulated:

- ❖ It is hypothesized that there will be significant effect of boxing bout on metabolic parameters (Insulin, Glucose, Lactate level, Triglycerides, Total cholesterol, HDL, LDL, Creatine) after boxing bout.
- ❖ It is hypothesized that there will be significant effect of boxing bout on inflammatory parameters (ALT, AST, Lctate dehydrogenase) which help to indicate muscle damage on individual.
- ❖ It is hypothesized that there will be significant effect of boxing bout on lipids and hormones (total cholesterol, triglyceride, high-density lipoprotein (HDL), and low-density lipoprotein (LDL), GH, ACTH).

DEFINITION AND EXPLANATION OF TERMS

ALT (Alanine Amino transferase): This enzyme is found mainly in your liver. Smaller amounts of ALT are in your kidney and other organs; too. Your body uses ALT to break down food into energy. Normally, ALT levels in the blood are low. If your liver is damaged, it will release more ALT into your blood and levels will rise.[1]

AST (Aspartate amino transferase): AST (aspartate amino transferase) is an enzyme that is found mostly in the liver, but also in muscles. When your liver is damaged, it releases AST into your bloodstream. An AST blood test measures the amount of AST in your blood. The test can help your health care provider diagnose. An AST blood test is often included in a routine blood screening. The test may also be used to help diagnose or monitor liver problems.[2]

LIPID PROFILE- Cholesterol travels through the blood on proteins called "lipoproteins." Two types of lipoproteins carry cholesterol throughout the body:

LDL (low-density lipoprotein)**,** sometimes called "bad" cholesterol, makes up most of your body's cholesterol. High levels of LDL cholesterol raise your risk for heart disease and stroke.

HDL (high-density lipoprotein), or "good" cholesterol, absorbs cholesterol and carries it back to the liver. The liver then flushes it from the body. High levels of HDL cholesterol can lower your risk for heart disease and stroke. When your body has too much LDL cholesterol, the LDL cholesterol can build up on the walls of your blood vessels. This buildup is called "plaque." As your blood vessels build up plaque over time, the insides of the vessels narrow. This narrowing blocks blood flow to and from your heart and other organs. When blood flow to the heart is blocked, it can cause angina (chest pain).

INSULINE: Insulin is a hormone created by your pancreas that controls the amount of glucose in your bloodstream at any given moment. It also helps store glucose in your liver, fat, and muscles. Finally, it regulates your body's metabolism of carbohydrates, fats, and proteins. "Without proper insulin function, your body can't store glucose in your muscles or

[1]https://www.healthline.com/health/alt#results
[2] https://medlineplus.gov/lab-tests/ast-test/

liver, but neither can it make any fat. Instead, the fat breaks down and produces, among other things, keto acids," says endocrinologist. If the levels of these acids grow too high, the imbalance can trigger diabetic ketosis, a potentially fatal condition.

When you eat, your blood glucose levels rise, and this leads a typical person's pancreas to release insulin, so that the sugar can be stored as energy for later use. Without that pancreatic ability, as a person with type 1 diabetes or type2 diabetes, your blood sugar levels may rise dangerously high, or drop too low. Insulin is a chemical messenger that allows cells to absorb glucose, a sugar, from the blood. The pancreas is an organ behind the stomach that is the main source of insulin in the body. Clusters of cells in the pancreas called islets produce the hormone and determine the amount based on blood glucose levels in the body. The higher the level of glucose, the more insulin goes into production to balance sugar levels in the blood. Insulin also assists in breaking down fats or proteins for energy.[3]

GLUCOSE: Glucose is key to keeping the mechanisms of the body in top working order. When our glucose levels are optimal, it often goes unnoticed. But when they stray from recommended boundaries, you'll notice the unhealthy effect it has on normal functioning. So glucose is the simplest of the carbohydrates, making it a monosaccharide. This means it has one sugar. It's not alone. Other monosaccharides include fructose, galactose, and ribose. Along with fat, glucose is one of the body's preferred sources of fuel in the form of carbohydrates. People get glucose from bread, fruits, vegetables, and dairy products. You need food to create the energy that helps keep you alive.

LACTATE: Lactate is the result of the metabolism of glucose during Tissue hypoxia whereby lactate, ATP, and water are produced. Tissue hypoxia and poor tissue perfusion can lead to hyperlactatimia, which can also result from other mechanisms. Blood lactate levels are a reflection of the difference between production and elimination, with the liver being responsible for the majority of lactate clearance. Normal blood lactate levels for the term infant depend on local established values and have been reported at <2.0 mmol/L. Arterial, venous, and capillary values for lactate levels have been used clinically, with most reporting good correlation between the sample types. Samples should be run within 15 minutes to prevent lactate levels from increasing prior to testing. Lactate values have a

[3] Medically reviewed by Maria Prelipcean, M.D.— Written by Adam Felman on November 21, 2018

useful role in the assessment of the newborn. Lactate measured in unbialical cord blood was shown to agree with pH and BE and has similar predictive value for short-term morbidities compared to pH and BE. A retrospective study of term infants with intrapartum asphyxia comparing the predictive value of pH, base deficit, and lactate for the incidence of moderate to severe hypoxic encephalopathy (HIE) showed that the highest lactate levels in the first hours of life are important predictors of moderate to severe HIE. Measurement of serum lactate is very helpful in differentiating increased acid production (e.g., due to inadequate tissue oxygen delivery) from loss of bicarbonate, such as occurs in renal tubular acidosis. [4]

CREATINE: Creatine is a substance that is found naturally in muscle cells. It helps your muscles produce energy during heavy lifting or high-intensity exercise. Taking creatine as a supplement is very popular among athletes and bodybuilders in order to gain muscle, enhance strength and improve exercise performance Chemically speaking, it shares many similarities with Your body can produce it from the amino acids glycine and arginine. Several factors affect your body's creatine stores, including meat intake, exercise, amount of muscle mass and levels of hormones like and IGF-1 About 95% of your body's creatine is stored in muscles in the form of phosphocreatine. The other 5% is found in your brain, kidneys and liver). When you supplement, you increase your stores of phosphocreatine. This is a form of stored energy in the cells, as it helps your body produce more of a high-energy molecule called ATP. ATP is often called the body's energy currency. When you have more ATP, your body can perform better during exercise. Creatine also alters several cellular processes that lead to increased muscle mass, strength and recovery.

LDH: Lactate dehydrogenase (LDH) is an important enzyme of the anaerobic metabolic pathway. It belongs to the class of oxidoreductases, with an enzyme commission number EC 1.1.1.27. The function of the enzyme is to catalyze the reversible conversion of lactate to pyruvate with the reduction of NAD+ to NADH and vice versa. The enzyme is present in a variety of organisms that include plants and animals. It is ubiquitously present in all tissues and serves as an important checkpoint of gluconeogenesis and DNA metabolism. A

[4] Yacov Rabi, Derek Kowal, Namasivayam Ambalavanan,10 - Blood Gases: Technical Aspects and Interpretation,
Editor(s): Jay P. Goldsmith, Edward H. Karotkin, Martin Keszler, Gautham K. Suresh,Assisted Ventilation of the Neonate (Sixth Edition),Elsevier,2017,Pages 80-96.e3,ISBN 9780323390064,https://doi.org/10.1016/B978-0-323-39006-4.00010-7.(https://www.sciencedirect.com/science/article/pii/B9780323390064000107)

species-wide analysis of LDH demonstrates its well-preserved structure with only a few changes in the amino acid sequence across species. The structural similarity with slight amino acid changes provides a logical platform for designing functional molecules to modulate the catalytic potential and expression of the enzyme. This article will focus on the biochemical function, testing methods, and clinical relevance of the LDH enzyme.[5]

ACTH: Adrenocorticotropic hormone (ACTH) is a tropic hormone produced by the anterior pituitary. The hypothalamic-pituitary axis controls it. ACTH regulates cortisol and androgen production. Diseases associated with ACTH include Addison disease, Cushing syndrome and Cushing disease. Pro-opiomelanocortin (POMC) gives rise to ACTH and melanocyte-stimulating hormone (MSH). This association is clinically important for Addison disease. ACTH receptors are in the adrenal cortex, in particular, the zona fasciculata and zona reticularis. The receptors are G protein-coupled receptors thus stimulating adenylyl cyclase. This leads to an increase in intracellular cAMP and activation of protein kinase. The anterior pituitary produces ACTH. It is considered a tropic hormone. Tropic hormones indirectly affect target cells by first stimulating other endocrine glands. Corticotropin-releasing hormone (CRH) is released from the hypothalamus which stimulates the anterior pituitary to release adrenocorticotropic hormone (ACTH). ACTH then acts on its target organ, the adrenal cortex.

GH: HGH, produced by the pituitary gland, spurs growth in children and adolescents. It also helps to regulate body composition, body fluids, muscle and bone growth, sugar and fat Metabolism, and possibly heart function. Produced synthetically, HGH is the active ingredient in a number of prescription drugs and in other products available widely over the Internet.

CORTISOLE: Cortisol, a steroid hormone, is synthesized from cholesterol. It is synthesized in the zona fasciculata layer of the adrenal cortex. Adrenocorticotropic hormone (ACTH), released from the anterior pituitary, functions to increase LDL receptors and increase the activity of cholesterol desmolase, which converts cholesterol to pregnenolone and is the rate-limiting step of cortisol synthesis.

[5] Farhana A, Lappin SL. Biochemistry, Lactate Dehydrogenase. [Updated 2021 May 7]. In: StatPearls [Internet]. Treasure Island (FL): StatPearls Publishing; 2021 Jan-. Available from: https://www.ncbi.nlm.nih.gov/books/NBK557536

SIGNIFICANCE OF THE STUDY

Boxing demands a high level of physical and physiological fitness. A well planned and regulated training regime can bring the athlete to his peak performance level by developing physical and physiological fitness is directly depending upon biochemical variables found in our body. The study is indicating the effect sparing on selected biochemical variables. The study will help the profession by way of highlighting the effect of boxing on biochemical variables. The study is throwing some light by virtue of scientifically developed training schedule for boxers in order to bring about optimum development of performance.

The study may significant in the following ways

1. The study may add new knowledge in the field of research of physical education in general and particularly in field boxing.
2. The findings of present study may reveal the contributing factors of biochemical parameters in boxing.
3. The result of the study may help coaches and trainees to train players according to their blood chemical variables.
4. With the involvement of higher authorities in this research, this study will provide directions to enhance sports performance at a higher level with taking care of the athlete's health.
5. The result of the study may be proving as a panacea to the area of sports medicine by curing imbalance in physiological and biochemical variables without taking any medicine or any other substance.
6. This study may help the coaches, athletes and exercise scientists who were in great need of an additional investigation of this problem.
7. This study may help the Physical Education teachers and Coaches to develop training program for boxers and understand the importance of biochemical level of boxers to achieve excellence.
8. The study can provide the knowledge about the biochemical aspects of boxers.
9. This study may be helpful in strength training program focusing on major biochemical parameters effecting performance of boxers.
10. The result of the study may be useful in supporting the training, evaluation, and development of the athletic performance of boxers.

CHAPTER II

REVIEWS OF RELATED LITERATURE

YAKUP KILIC (2019); Yakup Kilic (2019) conducted a study to examine the changes in metabolic, hormonal, and inflammatory responses in elite male boxers during a match. Twenty experienced boxers, each with over five years of practice, voluntarily participated. In order to asses plasma parameters blood samples were collected before and after from the boxers. The results indicated significant increases in glucose, lactate, metabolic hormones (insulin, ACTH, cortisol, and growth hormone), inflammatory markers (IL-1β, IL-6, and TNF-α), muscle damage indicators (ALT and AST), and the oxidative stress marker (SOD) following a nine-minute boxing match. Additionally, a potential decrease in total oxidant status (TOS) was observed. However, no significant changes were found in plasma levels of anabolic hormones (IGF-1), androgenic hormones (free and total testosterone), lipids (total cholesterol, triglycerides, HDL, LDL), kidney function markers (creatinine, urea), or minerals (iron and magnesium). The researchers concluded that the increased levels of energy fire and metabolic hormones might result from the high energy replacement during the match, while the rise in tissue damage and inflammatory markers could indicate trauma-related injuries. Understanding these metabolic changes during boxing matches can be beneficial for enhancing athlete performance, guiding recovery strategies, and minimizing injury risks.(Kılıc et al., 2019).

KILIC BAYGUTALP (2016) - This study looked at a few metabolic variables in boxing athletes both before and after training. The research comprised twenty boxing professionals. The individuals gave venous blood samples, and measurements were made of a few biochemical markers both before and six minutes after the battle. Following investigation, it was shown that combat exercise substantially raised serum levels of ACTH, AST, GGT, ALT, and GH and lowered serum levels of IGF (p0.05). When the results of our study's serum AST, ALT, and GGT levels are combined, we assume that muscular damage is the cause. In our study, training dramatically raised GH levels. It is a typical reaction to stress from exercise. His research adds more support to the idea that acute exercise has no effect on the plasma lipid profile. The study's findings imply that the boxing sport has a significant impact on a number of biochemical parameters, and that all biochemical parameters should

be carefully taken into consideration when assessing the laboratory test results of physically active individuals(Baygutalp et al., 2016).

OMAR KAYNA (2019): Kilic Baygutalp (2016) investigated the changes in certain metabolic variables in professional boxers before and after training sessions. The study included twenty experienced boxers who provided venous blood samples for analysis. These samples were taken both prior to training and six minutes afterward to measure specific biochemical markers. The findings indicated that training significantly increased serum levels of ACTH, AST, GGT, ALT, and GH, while serum levels of IGF were diminished consoderably ($p < 0.05$). The elevated levels of AST, ALT, and GGT observed in the study were attributed to potential muscle damage. Additionally, the significant rise in GH levels was identified as a normal response to the stress caused by intense exercise. The study also confirmed that acute exercise did not lead to any notable alteration in the plasma lipid profile, aligning with earlier research. These results highlight the substantial impact of boxing on various biochemical parameters. The study underscores the importance of carefully considering these markers when evaluating laboratory test results for individuals engaged in high levels of physical activity, as they provide critical insights into the physiological effects of the sport(Kaynar, 2019).

BILIC, MUHAMMAD (2019) This study aimed to examine the effects of acute sub-region sparring training on various blood biochemical markers in elite male boxers. The research involved 22 members of the national boxing team, all in excellent health (mean age: 18.36±6.18 years, mean body weight: 65.23±11.75 kg, mean height: 174.18±8.67 cm), who voluntarily participated. Blood samples were collected from the athletes both before and after the sparring session. Within an hour, the samples were transported to a laboratory where they were centrifuged at 4000 rpm for ten minutes to prepare them for biochemical analysis. Serum analysis was conducted using an auto analyzer. Data analysis was performed using SPSS statistical software. The ‘Shapiro-Wilk test’ assessed the normality of the data distribution, while descriptive statistics and the paired t-test were used for statistical evaluations. Results showed a statistically significant reduction in high-density lipoprotein cholesterol (HDL), direct bilirubin, and total bilirubin levels following the sparring session ($p < 0.05$). The findings suggest that punches to the lower region during sub-region sparring did not cause significant changes in the studied parameters. Moreover, the effects observed were consistent with other studies in the literature, indicating that this type of sparring does not

produce unique biochemical alterations compared to other training methods.(Bilici & Güler, 2019)

EL-ASHKER1 SAID (2012): Boxing, as a combat sport, involves high-intensity movements performed across multiple rounds with brief rest periods and limited recovery. Understanding the physiological and biochemical changes resulting from boxing training is crucial for physiologists. This study investigated the effects of boxing training on the physiological and biochemical responses of Egypt's elite boxers. Seventeen male boxers, aged 18 to 23, all registered with the Egyptian Boxing Organization, participated in the study. Measurements of physiological and metabolic functions were taken before and after the training program, and the data were analyzed using the Student's t-test to compare pre- and post-training results.

The results revealed significant increases ($p < 0.05$) in peak heart rate (HRPeak), relative and absolute VO2Max, Creatine Kinase (CK), and Lactate Dehydrogenase (LDH) levels following the training. In contrast, resting heart rate (HRrest), recovery heart rates at 1 minute (RHR1st), 2 minutes (RHR2nd), and 3 minutes (RHR3rd), respiratory exchange ratio (RER), and blood lactate (BL) concentrations showed significant decreases ($p < 0.05$). The study concluded that boxing training induces notable physiological and biochemical changes in elite athletes. These findings provide valuable insights for assessing, planning, and optimizing training regimens to enhance performance and recovery in boxers.(El-Ashker & Nasr, n.d.).

ASHOK KUMAR GHOS (2010): Ashok Kumar Ghosh (2010) conducted a study to analyze the physiological responses of amateur boxers during various activities, focusing on lab-based assessments. The research was divided into three phases: Phase 1 involved measuring the VO2max of six elite Indian national boxers using treadmill tests; Phase 2 evaluated their performance in a simulated boxing arena; and Phase 3 involved monitoring heart rates and blood lactate levels during sparring sessions.

The average VO2max recorded on the treadmill was 59.5 ± 4.7 ml/kg/min. During four simulated 2x4 rounds, the boxers exhibited average VO2 values of 56.1, 57.5, 57.7, and 59.3 ml/kg/min. Peak heart rates during sparring reached 192 bpm, and blood lactate levels were recorded at 13.6 mmol/L, both higher than what is typically observed in most intermittent sports. The study concluded that boxing places intense demands on the body’s cardiorespiratory and metabolic systems. Amateur boxers competing in 2x4 rounds need to

build resilience to maintain elevated heart rates and manage high blood lactate levels, highlighting the necessity of specialized training programs tailored to these physiological challenges. (Ghosh, 2010).

OBIMUNSK Z. (2014); The study aimed to assess the physiological demands of two non-contact boxing drills and three consecutive official matches held over three days. The drills mimicked match conditions, following a format of four rounds of two minutes each, with one-minute intervals between rounds. The assessment focused on specific hormones and metabolites, analyzed from blood samples collected just before the competitions and during the initial recovery period post-match. The study involved a female amateur boxer who competed in a three-day Polish Boxing Championship, with one match each day. Capillary blood samples were collected at three time points for each drill and match: ten minutes before the effort, and three and thirty minutes afterward. Blood lactate (LA) levels were measured, while serum levels of cortisol (C), testosterone (T), glucose (G), urea (U), and creatine kinase (CK) were also assessed. Additionally, the boxer provided a perceived fatigue (PF) rating after each exertion. The findings revealed that levels of G, C, and T were significantly higher during official matches compared to non-contact drills. Post-effort levels of G, C, T, and LA were consistently higher than pre-effort levels. Stress responses were more pronounced during official matches compared to drills with similar time structures and modalities. Changes in blood biomarkers strongly correlated with the perceived fatigue experienced by the athlete. (Obmiński & Turowski, 2014).

SIKVEIRA V. (2016): This study examined the physiological responses of 25 male professional mixed martial artists during official mixed martial arts (MMA) competitions and sparring sessions. Blood samples were collected before and after bouts in both settings. A two-way analysis of variance was used to compare the dependent parametric variables. The participants were 26.5 ± 5 years old, weighed 80 ± 10 kg, had a height of 1.74 ± 0.05 m, and had an average training experience of 39.4 ± 25 months.

The findings indicated that participants in the official competition (OFF) group exhibited higher blood glucose levels before matches and elevated ALT levels both before and after the bouts. Blood lactate responses were similar in both the official and simulated bouts. The study concluded that both official and simulated MMA bouts impose high glycolytic demands. However, no significant changes in biochemical markers of muscle damage were

observed immediately after the fights. Increased glycolytic activity was only evident in response to official matches prior to the bouts(Silveira Coswig et al., 2016).

GHOSH AK (1995); The study aimed to evaluate the aerobic-anaerobic metabolism and training status of 26 senior national-level boxers by analyzing their heart rate (HR) and blood lactate responses during competitive bouts. Aerobic capacity (VO2 max) was measured using a graded treadmill running protocol. Heart rate and blood lactate levels were recorded during the warm-up and throughout the boxing rounds. The results revealed that boxers in the heavyweight category had a significantly lower mean relative VO2 max compared to other weight classes ($P < 0.05$). Heart rate and blood lactate levels remained consistent across weight classes and rounds, except for the 48–57 kg category, where lactate levels were significantly higher in the second and third rounds compared to the first ($P < 0.05$). When data from all weight categories were combined, the average heart rate was 178 beats per minute, and the mean blood lactate concentration was 8.24 mMol/l. The findings indicate that amateur boxers demonstrate similar anaerobic adaptations regardless of weight class or aerobic capacity. To maintain performance, boxers must sustain high heart rates (around 180 beats per minute) and elevated blood lactate levels (approximately 9.0 mMol/l) throughout a training session.(Ghosh et al., 1995).

WIECHMANN G J (2016) This study investigated the factors affecting serum muscle damage marker (MDM) responses following mixed martial arts (MMA) contests. Ten elite male MMA athletes (mean age 28±5.7 years) participated, with creatine kinase (CK) activity and myoglobin (Mb) concentrations measured at four intervals: before the match, two hours after, 24 hours after, and 96 hours after. Video analysis was used to identify potential predictors, including the number of unsuccessful upright punches and kicks (UKF), strikes to the upper and lower body (LBH), and total fight duration (TFD). Results showed that Mb levels reached their peak at two hours post-match (210±122 µg/L-1), while CK levels peaked 24 hours post-match (829±753 U/L-1). Analysis revealed that LBH and UKF accounted for approximately 80% of the variation in peak CK levels, while TFD and LBH explained 87% of the variation in Mb levels. The study concluded that MMA causes significant muscle damage, primarily influenced by strikes to the lower body. Additionally, the MDM response is affected by eccentric muscle contractions used to control missed kicks and the total duration of the match. (Wiechmann et al., 2016).

ZULIANI U (1985) ; Extended or intense muscle activity can lead to significant changes in the levels of substrates and enzymes involved in muscle function. Elevated concentrations of creatine kinase (CK) and myoglobin in the blood are commonly observed in individuals engaging in physically demanding activities, often linked to repetitive and high-intensity muscle strain in various sports. To examine this phenomenon, a study was conducted on amateur boxers to compare the effects of non-traumatic exercise (shadow boxing) and high-impact activity (actual boxing) on specific humoral markers, including CK and myoglobin. The results indicated that blood levels of CK and myoglobin were notably higher after actual boxing compared to shadow boxing.

HUKKANEN, E, K. The study, published in *The Journal of Strength and Conditioning Research*, examined the impact of sparring on reaction time and punch force for straight punches in national-level boxers during precompetition and competition periods. Seven male boxers (age: 20.3 ± 2.7 years; height: 1.80 ± 0.06 m; weight: 73.8 ± 11.1 kg) participated. Heart rate and blood lactate levels were also recorded. Sparring sessions followed standard rules, consisting of three 3-minute rounds with 1-minute breaks. Results showed that the reaction time for the rear straight punch significantly increased ($p < 0.01$) after the third round in the precompetition period (to 390 ms) compared to the competition period (to 310 ms). For the lead straight punch, reaction time increased between the first and third rounds during the precompetition phase ($p \leq 0.05$) but remained stable during the competition period. Punch force measurements indicated that both rear and lead straight punches were stronger in the precompetition phase than in the competition phase at all measurement points. Punch force also increased between the first and third rounds, peaking after the third round in both periods (209 kg for rear straight in precompetition vs. 176 kg in competition). Blood lactate levels rose progressively across all rounds, reaching the highest values after the third round (17 mmol/L in precompetition vs. 13 mmol/L in competition). The observed differences in reaction time and punch force between precompetition and competition periods likely reflect variations in training volume and intensity, as well as the specific goals of explosive strength and boxing-focused training during these phases.

CHABENE, H., (2015); Boxing is one of the oldest combat sports. This review aims to critically analyze the physical and physiological characteristics of amateur boxers and provide recommendations for future research and training program development. Both male and female elite boxers typically have low levels of body fat. While limited research exists on

boxer somatotypes, elite male boxers are often characterized by a mesomorphic build, featuring well-developed muscle mass and minimal body fat. Athletes of both genders must maintain high levels of physical fitness to handle the metabolic demands of a boxing match and recover efficiently between rounds. International-level boxers demonstrate notable anaerobic power output and peak performance. Strong muscles in the upper and lower limbs are crucial for success in boxing, as they contribute significantly to the quick, dynamic nature of punches. Effective boxing performance at the elite level requires well-developed muscular strength and power in both upper and lower limbs. The limited available research indicates a relationship between isometric strength and elite boxing performance. Further studies are necessary to better understand the anatomical and physiological traits of boxers, enhance existing data quality, and develop optimal training programs tailored to these findings.

KOCAHAN, SAYAD (2021): The aim of the study was to investigate the impact of basketball training on the levels of creatinine, urea, and electrolyte balance in young athletes. **Methods and Procedures**: The research involved 34 healthy young boys, who were randomly divided into two groups: a training group (n = 17) and a control group (n = 17). Participants in the training group engaged in basketball practice for two hours per day, five days a week, over the course of eight weeks.The study revealed a significant increase in the levels of urea, creatinine, and plasma minerals among the training group. The findings demonstrated that the basketball training notably influenced blood urea nitrogen, urea, and creatinine levels.(Kocahan et al., 2021).

MANNA (2009): 2009 study by Manna aimed to investigate the impact of training on selected physiological and biochemical traits in Indian football players across various age groups. Out of 120 participants, 30 were divided into four groups: under-16 (U16), under-19 (U19), under-23 (U23), and senior (SR). The training program consisted of two phases: an eight-week Preparatory Phase (PP) and a four-week Competitive Phase (CP), conducted for four hours a day, five days a week, incorporating aerobic, anaerobic, and skill development exercises. Several physiological and biochemical markers were assessed at the beginning of PP and CP, as well as at the end (baseline data, BD). Compared to BD, some groups exhibited significant improvements in lean body mass, vo2 max, anaerobic power, grip and back strength, urea, uric acid, and high-density lipoprotein cholesterol (HDL-C) during the PP and CP phases of the training. Conversely, body fat, hemoglobin, and total cholesterol levels decreased significantly in certain groups.(Manna et al., 2010).

MANNA et al (2011): This study investigated the effects of a structured training program on the morphological, physiological, and biochemical parameters of male soccer players under 19 years old. The participants included 30 Indian soccer players aged 16 to 18.99 years. The training program was conducted over two distinct phases: an 8-week Preparatory Phase (PP) followed by a 4-week Competitive Phase (CP). The regimen consisted of four-hour training sessions, five days a week, incorporating aerobic exercises, anaerobic drills, and skill development activities. Measurements were recorded at the beginning of PP, the start of CP, and at the end of the program (baseline data). The findings showed significant reductions in stature, body mass, maximum heart rate, triglycerides, and HDL-C levels. Conversely, there were notable increases in lean body mass, VO2 max, anaerobic power, grip and back strength, urea, and uric acid levels, along with decreases in hemoglobin, total cholesterol, and body fat percentage. (Manna et al., 2011)

MANNA et al., (2016); Indranil Manna (2016) conducted a study to examine the effects of training on specific anthropometric, psychological, and physiological parameters in Indian hockey players under 23 years old. **Methodology:** Thirty male hockey players (average age: 20.9 ± 1.0 years; age range: 19.00–22.99 years) participated voluntarily. The training program was divided into two phases: an eight-week Preparatory Phase (PP) and a four-week Competitive Phase (CP). Players trained for four hours daily, five days a week, focusing on aerobic and anaerobic conditioning as well as skill development. Selected variables were measured at baseline (zero level), the end of PP, and the conclusion of CP. The results showed significant ($P<0.05$) improvements in anaerobic power, grip and back strength, serum urea, serum uric acid, and HDL-C levels, along with notable reductions in body fat percentage, recovery heart rate, hemoglobin, total cholesterol, and triglycerides. However, no significant changes were observed in height, body mass, lean body mass (LBM), maximum heart rate (HRmax), VO2 max, or LDL-C levels. Given the limited data available on Indian hockey players, this study provides valuable insights that can assist coaches in designing effective training programs. (Manna et al., 2016)

ZBIGNIW OBMINSKI (2010): A study was conducted to monitor changes in morning biochemical blood parameters in elite female judo athletes (n = 12) during a 12-day training camp held at a moderate altitude of 2300 meters above sea level. The training began after a one-month detraining period, and the athletes lived and trained at the altitude throughout the camp. Biochemical parameters, including hematocrit (Hct), glucose (G), urea (U), and plasma

creatine kinase (CK), were measured in the mornings on specific days of the training period. During the first few days (days 2, 3, and 4), the athletes engaged in training sessions that were less intense compared to their typical regimen at sea level. Initial findings revealed that levels of Hct, G, CK, and U were lower after the first night's sleep at altitude but increased in subsequent days. A significant correlation was observed between G and CK on the first day of the camp ($r = 0.641^*$, $n = 12$) and over the entire seven-day observation period ($r = 0.587^*$, $n = 84$). Body mass and baseline CK levels also showed strong correlations on the first day ($r = 0.940^*$, $n = 12$) and throughout the camp ($r = 0.911^*$, $n = 84$). The increase in Hct during the camp was attributed to a reduction in blood plasma volume over time. While G and U levels showed less variability, CK exhibited greater fluctuations, indicating more pronounced changes in muscle strain and recovery compared to metabolic stability. Overall, the altitude training resulted in gradual decreases in plasma volume and modest changes in the biochemical parameters assessed. (Obmiński et al., 2010)

RODRIGUES NETO (2015) The study aimed to evaluate the long-term impact of regular physical activity on biochemical markers, body composition, and motor function in women involved in the Family Health Strategy. A total of 21 women, aged 49±10 years, participated and were divided into two groups. The experimental group (EG=14) engaged in a structured exercise program three times a week for 24 weeks, which included walking, water aerobics, and gym sessions. In contrast, the control group (CG=7) did not receive any intervention. The study assessed biochemical markers, body composition, and motor function. Results for the EG indicated a significant increase in HDL levels ($p=0.006$) and a significant decrease in triglycerides ($p=0.025$). For the CG, there was a significant rise in triglycerides ($p=0.014$) and VLDL levels ($p=0.040$). No significant differences in body composition were observed between the groups ($p>0.05$). However, the EG showed significant improvements in arm flexion strength ($p=0.018$) and static strength ($p=0.007$). In conclusion, the structured exercise program enhanced motor performance and metabolic markers despite no observed changes in body composition factors.(Neto et al., 2015).

Indranil Manna (2016) highlighted that boxing is an intermittent sport characterized by short, intense bursts of activity. Performance in the sport depends heavily on a well-developed aerobic system and high anaerobic fitness, alongside technical skill, strategy, and physiological readiness. This study investigated the anthropometric, physiological, and biochemical profiles of elite female Indian boxers. Fifty female boxers, aged 17–23, from the

Indian National Camp participated in the research. Laboratory assessments included measurements of height, body mass, body fat percentage, lean body mass (LBM), VO2max, anaerobic power, strength, hemoglobin (Hb), serum urea, uric acid, total cholesterol (TC), triglycerides (TG), high-density lipoprotein cholesterol (HDL-C), and low-density lipoprotein cholesterol (LDL-C). Optimal levels were recorded for body fat, VO2max, anaerobic capacity, hemoglobin, total cholesterol, triglycerides, and HDL-C. Additionally, VO2max demonstrated a negative correlation with body mass and body fat, indicating that higher body mass and fat content were associated with reduced aerobic capacity. Given the limited research on female boxers in India, this study provides valuable insights that can help athletes and coaches design effective training programs. It also underscores the need for government and non-governmental organizations to promote women's participation in boxing. (Manna, 2016).

Demirhan (2020) conducted a study to evaluate the hematological and biochemical characteristics of Olympic Greco-Roman wrestlers across different phases of their training season. Measurements were taken at three intervals: just before the start of the training session, three months into the season, and six months later. Blood samples were collected from the athletes both before and after exercise to analyze the markers. The study revealed significant increases ($p<0.05$) in total leukocyte, lymphocyte, and neutrophil levels across all three time points (baseline, three months, and six months) when compared to pre-exercise values. Biochemical analyses showed that blood glucose levels were significantly lower post-exercise at all three intervals. Additionally, HDL cholesterol levels increased significantly ($p<0.05$), while LDL cholesterol levels decreased significantly ($p<0.05$) after exercise.

The findings suggest that fatigue exercise led to a notable rise in total leukocyte, lymphocyte, and neutrophil counts, although other hematological parameters remained largely unaffected. Post-exercise, the wrestlers experienced a reduction in blood glucose and LDL cholesterol levels, along with an increase in HDL cholesterol levels. However, the six-month training period did not produce significant changes in the overall hematological or biochemical markers across the three assessment points. (Demirhan et al., 2020)

U ZULIANI (1995); U. Zuliani (1995) studied the impact of different types of muscular activity on specific humoral markers, focusing on myoglobin and creatine kinase (CK) levels. Physical activities, particularly prolonged or intense ones, are known to cause significant changes in the substrates and enzymes involved in muscle contraction. Individuals engaged in

physically demanding tasks often exhibit notable increases in blood CK and myoglobin levels, a phenomenon commonly associated with repetitive and severe muscle strain observed in many sports. The study investigated amateur boxers to compare the effects of basic muscular activity, such as shadow boxing, with more intense, trauma-inducing actions like actual boxing. The findings revealed that blood concentrations of CK and myoglobin were significantly higher after actual boxing than after shadow boxing, highlighting the greater muscular and biochemical impact of traumatic physical activity. (Zuliani et al., 1985)

TSOPANAKIE (1986); Tsopanakie (1986) conducted a study to investigate the effects of elite-level training in nine Olympic sports specializations on plasma lipid markers. Over three years, the study analyzed total cholesterol (TC), total lipids, triglycerides, HDL, LDL, VLDL, and the percentage distribution of these lipoproteins in elite athletes. Additionally, the study examined the lipoprotein ratio factors (RF), including LDL/HDL and TC/HDL ratios. The findings revealed that athletes participating in short-distance and long-distance running, football, volleyball, judo, and other sports had significantly higher HDL levels compared to the control group. Furthermore, a notable reduction in LDL levels was observed across all four sports categories combined. While there was only a minor correlation between VO2 max or relative body weight and HDL or TC/HDL ratios, endurance sports, such as running and team sports like football, basketball, and volleyball, were associated with favorable HDL and RF values. These results suggest that endurance sports may provide protective benefits against atherogenesis by improving lipid profiles. In contrast, lipid levels in strength-based sports were found to be closer to normal. (Tsopanakis et al., 1986)

Rodrigo Aquino (2016) conducted a study to explore the relationship between indirect markers of muscle damage and movement patterns during a simulated soccer game among young players. The study also aimed to analyze and compare players' tactical performance during the first and second halves of the game. Eighteen youth soccer players participated, with blood samples collected before the game and 30 minutes afterward to measure levels of lactate dehydrogenase and creatine kinase. Displacement patterns and tactical variables were analyzed using functions developed in the MATLAB environment (MathWorks, Inc., Natick, MA, USA). The results showed significant increases in average speed ($P=0.05$), the number of sprints ($P<0.001$), the proportion of total distance covered at high intensity ($P<0.001$), and tactical variables such as team surface area ($P=0.002$) and spreading ($P=0.001$) during the second half of the game. Conversely, the proportion of total distance covered at low intensity

decreased significantly ($P \leq 0.05$) in the second period. Additionally, changes in movement patterns during the simulated game were strongly correlated with the percentage change in creatine kinase and lactate dehydrogenase levels. These findings underscore the importance of considering post-training recovery strategies, as the strong link between muscle damage markers and movement patterns highlights the physiological demands placed on young players during training simulations. (Gioldasis, 2016)

Indranil Manna (2010) conducted a study to evaluate the effects of training on key physiological and biochemical parameters in Indian football players across different age groups. The study involved 120 players divided into four groups (n = 30 each): under 16 (U16), under 19 (U19), under 23 (U23), and senior (SR). Training was conducted over two distinct phases: an eight-week Preparatory Phase (PP) and a four-week Competitive Phase (CP). Players trained for four hours a day, five days a week, with sessions focusing on aerobic, anaerobic, and skill development exercises. Measurements of physiological and biochemical indicators were taken at the start of PP and CP, as well as at the end of the training program (baseline data, BD).

The results revealed significant improvements ($P < 0.05$) in some groups, including reductions in body fat, hemoglobin (Hb), total cholesterol (TC), triglycerides (TG), and low-density lipoprotein cholesterol (LDL-C). Simultaneously, there were significant increases ($P < 0.05$) in lean body mass (LBM), VO2max, anaerobic power, grip and back strength, urea, uric acid, and high-density lipoprotein cholesterol (HDL-C). However, no significant changes were observed in body mass or maximum heart rate across the groups after the training program. The study highlights the impact of structured training on enhancing fitness and biochemical profiles in football players, emphasizing age-related adaptations. (Manna et al., 2010)

PHILIP DAVIS 2013 Philip Davis (2013) analyzed the activity profile of competitive novice-level amateur boxing (3 × 2-minute bouts) by examining film footage and post-bout blood lactate concentrations ([La]) in 32 male boxers (mean age: 19.3 ± 1.4 years; mean body mass: 62.6 ± 4.1 kg). The study found that winners executed significantly more lead-hand punches in the first round (34.2 ± 10.9 vs. 26.5 ± 9.4), landed more total punches to the head across all rounds (121.3 ± 10.2 vs. 96.0 ± 9.8), and performed more block-and-counterpunch combinations (2.8 ± 1.1 vs. 0.1 ± 0.2). Additionally, winners used more punching combinations in rounds 1 and 3 (44.3 ± 6.4 vs. 28.8 ± 6.7; all $P < 0.05$), landing an average of

18 ± 11 more punches than their opponents. The highest post-bout blood [La] measured in 16 boxers was 11.8 ± 1.6 mmol/L, regardless of match outcome. These findings indicate that maintaining a high frequency of offensive actions, particularly lead-hand straight punches to the head combined with striking combinations, is critical for success. Effective counterattacks must begin with defensive moves. Based on post-bout blood [La], boxers must be capable of sustaining technical proficiency at a high activity level while tolerating a lactate production rate of 1.8 mmol/L/min. (Davis et al., 2013).

RAGIP PALA (2013); Ragip Pala (2013) conducted a study involving 24 male coaches who trained national boxing teams, including 12 senior male and 12 senior female boxers, aged between 27 and 56 years. Blood samples were collected from the coaches both before and after matches, and the results were analyzed using laboratory data. Statistical analyses were performed using the PROC MEANS procedure in the SAS software package, with paired t-tests applied to determine significance at the $P < 0.05$ level. The findings revealed a statistically significant difference in glucose levels before and after matches ($P = 0.0365$). While insulin levels also varied, the difference was not statistically significant ($P = 0.7135$). Cortisol levels showed a significant increase post-match ($P < 0.001$), whereas urea levels decreased slightly, though the change was not statistically significant ($P = 0.0594$). Similarly, creatine levels showed a decrease, but the difference was not statistically significant ($P = 0.0745$). The study highlights significant changes in cortisol and glucose levels among national boxing team coaches, emphasizing the physiological responses associated with their roles during matches. (Alpay, 2013)

Nuri Muhammet Çelik 2017: The purpose of the study was to ascertain how much fluid male judokas participating at the U18 level lost after a training session. Seventeen male athletes from their national squad participated in the study. Prior to and during the competition, biochemical indicators such as blood urea nitrogen (BUN), creatinine, potassium levels, urine density, and urine pH were examined. The findings demonstrated that sudden fluctuations in body weight, which are frequently observed in combat sports, can result in long-term health issues. The study also looked at how the physical fitness metrics of 11–17-year-old judo practitioners and non-practitioners changed. According to the findings, judo practitioners had a greater anaerobic capacity than non-participants. Depending on age, training, and experience, participants' heart rates fluctuated, their pH changed, and their lactate levels rose during simulated judo competitions. The maximum oxygen consumption of

judo practitioners and their untrained peers did not differ significantly. Particularly during periods of strong adaptation, high levels of exertion during simulated judo tournaments led to sharp drops in pH and rises in lactate levels.

CHAPTER III

METHODOLOGY

In this chapter the procedure adopted for selection of subjects, selection of variables, criterion measures, collection of data, procedure for administration of tests, and statistical technique employed for analysis of data is presented.

SELECTION OF SUBJECTS

For the purpose of study more than 20 male boxing players of National level from Uttarakhand Age ranging between 17-25 years will be selected voluntarily as subjects for the study.

SELECTION OF VARIABLES

From researcher's own understanding of the problem and on the basis of discussion with experts, gleaned through the literature, the following variables are selected:

Biochemical variables include:

1. **Metabolic parameters.**

- Insulin
- Glucose
- Lactate level
- Triglycerides
- Total cholesterol
- HDL
- LDL
- Creatine

2. **Hormonal parameters.**

- ACTH
- GH
- Cortisole

3. **Inflammatory markers.**

- ALT
- AST

- Lactate dehydrogenase

ADMINISTRATION OF THE TEST

Test procedure- before any procedure all athletes will be explained experimental procedures and cause behind this study. This observational research includes biochemical tests performed on blood samples to investigate metabolic, hormonal, and inflammatory parameters. The first venous blood samples (4 mL) for measurement of pre-match values of the boxers will be taken 30 min before going for bout in order not to influence their performance. In order to determine the after-match data, the second blood samples of the boxers will be taken within 10 min at the end of 9 min high intense match.

STATISTICAL TECHNIQUE

In this study, initially the descriptive statistics will be used for different biochemical parameters(metabolic, hormonal and inflammatory) mean and standard deviation of all variables will computed in the first phase of data analysis. In the second t-test (paired sample t-test) will be used to know the difference (pre-post) in the selected biochemical variables.

All statistical functions will be performed with the SPSS software. The level of significance will be kept at 0.05 to test the hypothesis.